

## $C_{60}^+$ Cluster Source for Secondary Ion Mass Spectrometry

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**Vision:** The use of novel primary ion beams for use in Secondary Ion Mass Spectrometry (SIMS) has shown great promise in analysis of a range of materials from polymer films to semiconductors. Experimentation with cluster ion beams has the potential to expand the application of SIMS to provide answers to important questions concerning materials composition and structure.

**Purpose:** The purpose of this work was to explore the operation of a  $C_{60}^+$  cluster source on a magnetic sector SIMS instrument and to perform a preliminary investigation of unique applications of the source.

**Scientific:** Cluster ion sources have been shown to be useful for analysis of a wide range of material by Secondary Ion Mass Spectrometry (SIMS). Their relatively large-area dispersion of energy by cluster ions into a surface during sputtering reduces beam-induced damage and can also increase the relative yield of higher molecular weight species sputtered from the surface. Previous experiments performed here at NIST with other cluster ion beams such as  $SF_5^+$  have produced impressive results for sputtering and depth profiling of inorganic and organic materials. Recently  $C_{60}^+$  has been investigated for use in Time-of-Flight SIMS by other investigators with promising results.

**Major Accomplishments:** We obtained a  $C_{60}^+$  source of the type used by other investigators on ToF-SIMS instruments and fitted it onto our dynamic SIMS instrument. Initial experiments show that the source can produce 25-50 nA of  $C_{60}^+$  and  $\sim 25$  nA of  $C_{60}^{2+}$ . The ions are produced by electron impact on  $C_{60}$  vapor. The beam current produced is quite stable and can be focused into a usable spot at the sample surface. An initially unexpected result is that  $C_{60}^+$  does not produce any sputtering but instead, produces deposits at impact energies below  $\sim 12$  keV impact energy.

Depth profiling with the  $C_{60}^+$  ion beam was evaluated using a Ni/Cr multilayer test sample. This material typically roughens under ion bombardment making it difficult to discern

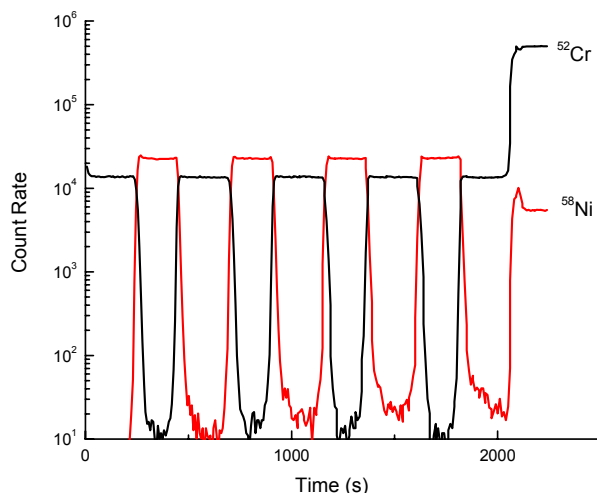


Figure 1. Depth profile of Cr-Ni multilayer obtained with  $C_{60}^+$ .

the sharp boundaries between the layers. results on samples such as the Cr-Ni multi-layer where surface roughening made it impossible to discern the sharp boundaries between the layers.

Figure 1 shows a depth profile of the Cr-Ni multi-layer obtained with 14.5 keV  $C_{60}^+$ . The layers are clearly defined in this profile, with near constant secondary ion intensity in each of the respective layers. This profile is comparable to those obtained by other investigators who used a ToF-SIMS instrument but is obtained in considerably less time due to the higher current density obtained in the NIST dynamic SIMS instrument.

In addition to depth profiling, the  $C_{60}^+$  source is capable of imaging on the scale of a few microns. An example image taken on a test-pattern sample is shown in Figure 2.

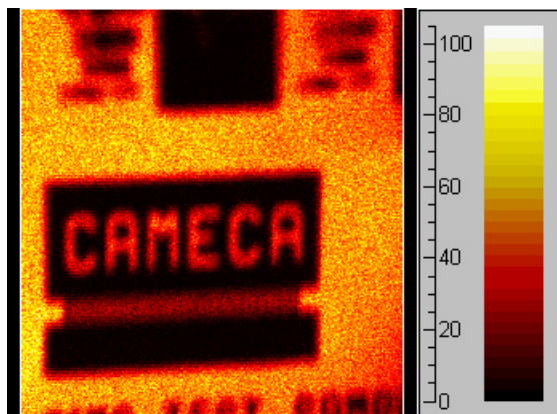


Figure 2. This shows a micro-beam image taken with  $C_{60}^+$ . The image is approximately 500x500  $\mu\text{m}$  across.

**Impact:** The use of this source will allow us to explore semiconductor depth profiling of ever-shallower implants. As the lateral size of devices become smaller so does the implant depth become shallower. Thus to characterize cutting-edge electronics one must have high depth resolution. In addition, pharmaceutical companies are becoming increasingly in novel drug delivery systems that, for development and quality control purposes, must be characterized by techniques such as SIMS. The use of cluster ion sources has shown promise with these systems and the exploration of the application of  $C_{60}$  to polymer depth profiling may improve the quality of this data even further.

**Future Plans:** Future plans involve the exploration of novel applications of the  $C_{60}$  ion source. One potential application may involve the measurement of nitrogen concentrations in ZrO films that are also used in the semiconductor industry. We plan to investigate the source parameters to obtain optimum performance of the source and the utilization of  $C_{60}^{2+}$  for sputtering and analysis.

**Programs:** Because of the general applicability of SIMS there may be applications of this novel ion source in a wide range of programs, however the ones that we have targeted are: Microelectronics, Biomaterials, Pharmaceuticals and Bio-manufacturing, and Technologies for Future Measurements and Standards. These are the areas where this new technology may have the greatest immediate impact.